

# BREAK IN THE HEAT WAVE ON THE EAST COAST, JULY 1957

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## 1. INTRODUCTION

During the latter half of July 1957 a heat wave occurred along the central Atlantic seaboard. The area affected extended from Connecticut southward to Virginia and inland from the coast to the Appalachians. This spell of intense hot weather was of short duration, lasting only two days, July 21 and 22, over most of this area. The maximum temperatures recorded during this period in the large populous centers such as New York, Philadelphia, Baltimore, and Washington, D. C., were sufficiently high to be noteworthy. The heat wave in the affected area ended as fast as it began. The welcomed relief was effected by the opportune passage of a polar cold front previously situated to the north and west of this area.

## 2. SURFACE TEMPERATURE AND PRECIPITATION

Table 1 shows the maximum temperatures occurring at the peak of the heat wave and the maximum temperatures following the passage of the polar cold front. As shown in the table, these relatively high maximum temperatures occurred most generally during the 21st and 22d. The exceptions were Albany and Providence which experienced high maximum temperatures on the 20th and 21st, and Richmond and Norfolk where warm maximum temperatures prevailed until the 23d. The maximum temperatures for these cities averaged 99° F. during the heat spell, which was 14° F. higher than the average normal maximum of 85° F. for the above-mentioned cities during the month of July. With the passage of the cold front the maximum temperatures dropped markedly. The decrease in maximum temperatures for these cities averaged 20° F.

During the heat wave, temperature records were established at Baltimore, Wilmington, Newark, and Providence. The 103° F. temperature in Baltimore on July 21 was the highest temperature experienced there since July 28, 1941, when the mercury also reached 103° F. In addition, a record maximum was established for the 22d with a temperature of 102° F. In Wilmington, a new maximum temperature record was established for the 22d and the maximum temperature high for the 21st was equalled. Maximum temperature records for the 20th, 21st, and 22d were established in Newark and for the 20th in Providence. Although no new record maxima were

established for the other cities listed in table 1, in some instances the temperatures recorded on the 21st and 22d were the highest for the past several years and closely approached the maximum temperatures for these dates. This was evidenced at Trenton where the consecutive 100° F. maxima on the 21st and 22d were the first such occurrence since July 1936, and at New Haven where the 100° F. maximum on the 22d was the highest since the 100° F. temperature that was recorded on August 27, 1948.

Although the passage of the cold front brought welcomed relief from the heat, the accompanying precipitation was rather disappointing in that it failed to bring any substantial relief from the drought that had plagued the Middle Atlantic States since spring. What rainfall did occur was of a spotty nature with some localities receiving little more than a trace while nearby sections received an inch or more. For example, Philadelphia, which suffered through the driest July on record, received

TABLE 1.—Record of maximum temperatures July 20–24, 1957, normal maxima [1] for July, and precipitation totals July 22–24, 1957 for selected stations.

Station	Date	Max. temp. (° F.)	Date	Max. temp. (° F.)	July normal max. temp. (° F.)	Precip. (in.)
Albany, N. Y. (Airport).....	20	95	23	79	82.5	0.01
	21	95	24	79		
Providence, R. I. ....	20	97	23	81	82.6	.15
	21	91	24	74		
	22	97				
New Haven, Conn. ....	21	90	23	81	80.1	.05
	22	100	24	80		
Bridgeport, Conn. ....	21	90	23	82	81.6	.03
	22	103	24	80		
New York, N. Y. (Central Park).....	21	100	23	82	84.7	.04
	22	101	24	84		
Newark, N. J. ....	21	99	23	83	84.9	.02
	22	101	24	83		
Trenton, N. J. ....	21	100	23	82	84.6	.25
	22	100	24	82		
Allentown, Pa. ....	21	100	23	78	85.5	.16
	22	100	24	82		
Harrisburg, Pa. ....	21	97	23	79	85.6	1.23
	22	97	24	78		
Philadelphia, Pa. (Airport).....	21	101	23	81	86.5	.17
	22	100	24	82		
Wilmington, Del. ....	21	102	23	81	86.7	.43
	22	101	24	83		
Frederick, Md. ....	21	100	23	78	87.9	.51
	22	100	24	79		
Baltimore, Md. (City Office)...	21	103	23	88	86.9	.49
	22	102	24	83		
Washington, D. C. (Airport)...	21	101	23	87	87.1	.15
	22	101	24	83		
Richmond, Va. (Airport).....	21	98	24	81	87.8	1.20
	22	100				
	23	95				
Norfolk, Va. (Airport).....	21	98	24	80	86.0	1.53
	22	99				
	23	98				

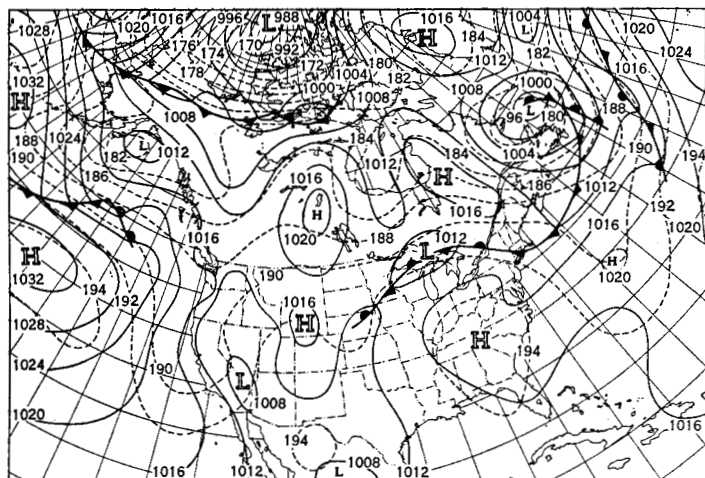


FIGURE 1.—Sea level pressure and 500-mb. chart at 1200 GMT, July 21, 1957. Sea level isobars (solid lines) are at 4-mb. intervals and 500-mb. isohypses (dashed lines labeled in hundreds of geopotential feet) are at 200-ft. intervals. Surface fronts are indicated with conventional symbols.

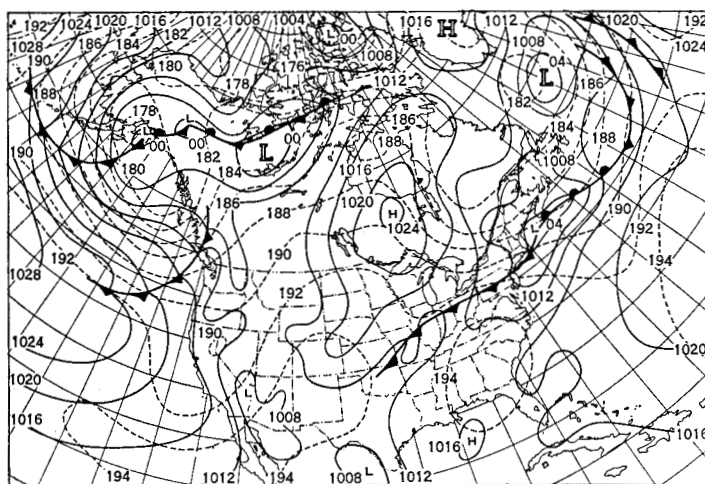


FIGURE 2.—Sea level pressure and 500-mb. chart at 0000 GMT, July 23, 1957. Sea level isobars (solid lines) are at 4-mb. intervals and 500-mb. isohypses (dashed lines labeled in hundreds of geopotential feet) are at 200-ft. intervals. Surface fronts are indicated with conventional symbols.

only 0.17 inch of rainfall while more than one inch fell at nearby Lyndell, Pa. (located 30 miles west of Philadelphia). Providence, recording its longest dry spell on record, received only 0.15 inch which approximated the average for southern New England. Some stations in northern West Virginia and southeastern Virginia (Norfolk area) recorded over two inches in a 24-hour period but only 0.15 inch fell at Washington National Airport, which hadn't experienced a drier July since 1872.

### 3. SYNOPTIC SITUATION—SURFACE MAPS

As indicated by the surface pattern in figure 1, the central and southern Atlantic seaboard was dominated by a flat amorphous extension of the Bermuda High. The center of this anticyclonic appendage was located

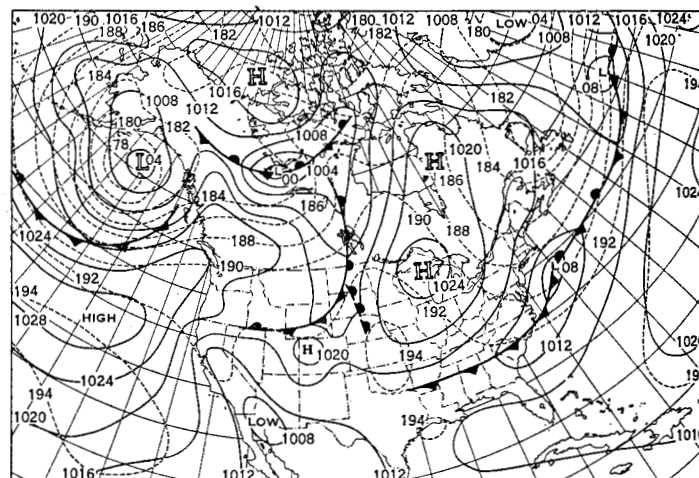


FIGURE 3.—Sea level pressure and 500-mb. chart at 1200 GMT, July 24, 1957. Sea level isobars (solid lines) are at 4-mb. intervals and 500-mb. isohypses (dashed lines labeled in hundreds of geopotential feet) are at 200-ft. intervals. Surface fronts are indicated with conventional symbols.

at 1200 GMT, July 21, 1957, slightly north of Athens, Ga.; the central pressure was 1019 mb. Historically this appendage was the remnant of a more potent High which had travelled eastward across western Canada and then southeastward into the States in the eastern Great Lakes region. A quasi-stationary cold front to the north with a flat wave in the Sault Ste. Marie area separated this feature from two colder Canadian Highs to the north and northwest.

Off the west coast of the United States, a significant feature was the well developed eastern cell of the Pacific High. This cell was surmounted to the north by a cyclonic vortex in the Gulf of Alaska. About midway between these two features stretched a maritime polar front with a wave crested in the vicinity of weather ship Papa (50°N., 145°W.).

Thirty-six hours later at 0000 GMT, July 23 (fig. 2) the quasi-stationary front of figure 1 had taken on more pronounced cold frontal characteristics and was moving down the middle Atlantic seaboard. The Bermuda High extension was melting away and the Canadian polar High which was to replace it was well poised behind the advancing front. In the Far West the center of the eastern cell of the Pacific High had diminished somewhat in intensity and had retrograded noticeably westward. Concurrently a maritime polar front was emerging from the Gulf of Alaska and approaching Tatoosh, Wash.

By 1200 GMT, July 24 (fig. 3) the cold front was well on its way down the Atlantic coast sweeping out the above normal temperatures which had previously prevailed and replacing them with noticeably lower ones. The source of the colder air was the Canadian High shown in figure 3 in the Lake Superior region.

### 4. SYNOPTIC SITUATION—500-MB. CHARTS

Superimposed on the surface maps in figures 1, 2, and

3 are the 500-mb. charts for the corresponding times. In total, they illustrate a characteristic upper air meteorological event, namely the passage of a short-wave trough over the top (to the north) of a stagnating flat ridge or High. Such short-wave troughs after passing the ridge position in more or less small amplitude and subdued forms of development, frequently pick up varying amounts of southward component in their motion and after passing several hundred miles downstream from the ridge line, quite often increase their amplitudes and intensities. Such a portrayal is in substantial agreement with Fultz's [2] suggested life cycle of the minor waves in conjunction with the major waves.

On some occasions, however, the position of redevelopment or intensification of this short-wave trough occurs at very close proximity to the ridge line, in fact, so close, that the High or ridge completely disappears in that area and is replaced by a cyclonic circulation. The emergence of this new (farther westward) large-scale trough position and the concomitant westward shift of the old ridge line represents the phenomenon known as "long-wave retrogression."

A comparison of figures 1, 2, and 3 shows that retrogression has indeed taken place. In figures 1 and 2, two salient features in the East in mid-latitude are the High centered over northern Georgia and the major trough line just east of Bermuda's longitude. In figure 3, the major trough line now lies along the east coast while its accompanying major ridge line to the west is located on the west side of the Mississippi River.

## 5. MEAN FLOW CHARTS

It has long been noted by many meteorologists that the determination of a long-wave position (trough or ridge) through the inspection of a single synoptic chart was often highly unsatisfactory, if not impossible. In an AROWA publication [3], it is claimed that "in all but the simplest situations, two meteorologists working independently would produce substantially different long-wave analyses." The authors of this publication also conclude that a method which they had previously proposed, using the tracks of 500-mb. height change centers for determining the position of long waves, would also not be completely satisfactory [3], [4]. The use of "time mean" charts for locating the long-wave positions on a current synoptic chart will also have its shortcomings. This has been pointed out by Martin [5] and others [3].

At NAWAC a space-averaged mean chart of the 500-mb. flow has been used for several years as a method for objectively determining the long-wave positions on any current synoptic chart. The grid length used is 12 degrees of latitude (measured at latitude 60° on a polar stereographic projection). The method of preparation, including the grid length used, follows the procedure recommended by Fjørtoft [6] and is similar to the method employed by the Air Weather Service [7].

Figures 4 and 5 are space-averaged mean charts for the

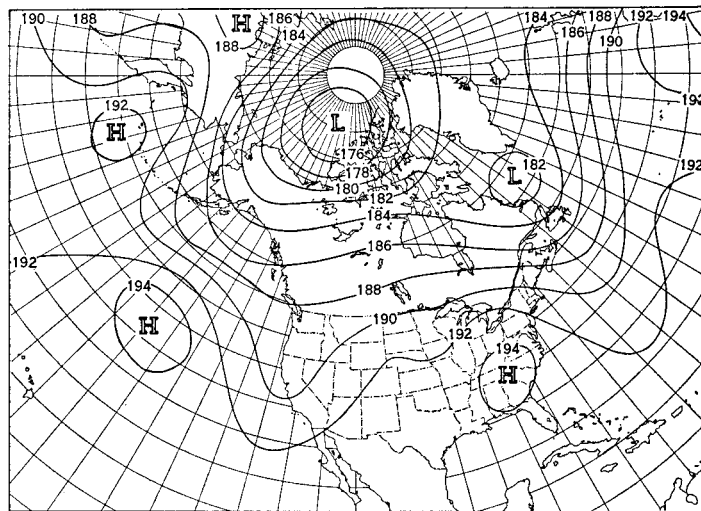


FIGURE 4.—Space-mean chart for 500 mb. at 1200 GMT, July 21, 1957.

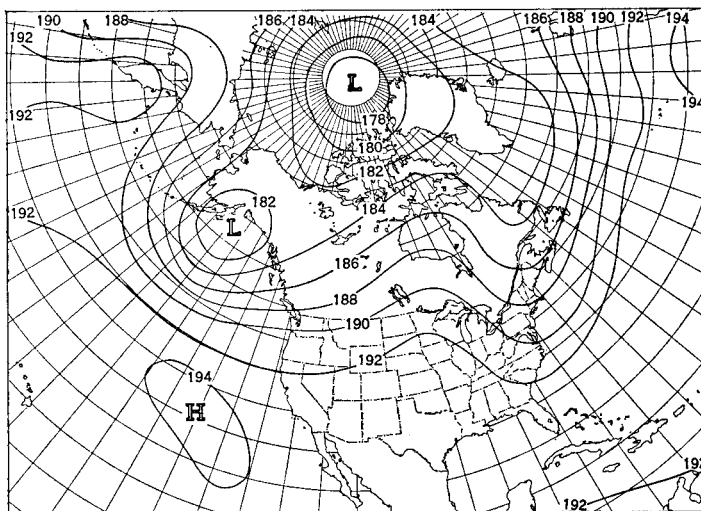


FIGURE 5.—Space-mean chart for 500 mb. at 1200 GMT, July 24, 1957.

indicated times. In figure 4, a long-wave trough position is indicated in the vicinity of a line running from latitude 55° N., longitude 53° W. to latitude 25° N., longitude 62° W. The long-wave ridge position is somewhat more nebulous but in the interval of latitudes 30° N. to 45° N. seems to lie somewhere between longitudes 80° W. and 85° W. Farther west another long-wave trough position is indicated just off the coast of California.

Seventy-two hours later, a drastic change has taken place (fig. 5). The long-wave trough position off the east coast has definitely retrogressed westward. The same is true for the long-wave ridge position in the United States. Off the west coast the long-wave trough position has also undergone a pronounced displacement to the west.

## 6. CROSS SECTION ANALYSIS

Cross section analyses (figs. 6 and 7) were prepared for 1200 GMT, July 21 (when the ridge pattern at 500-mb.

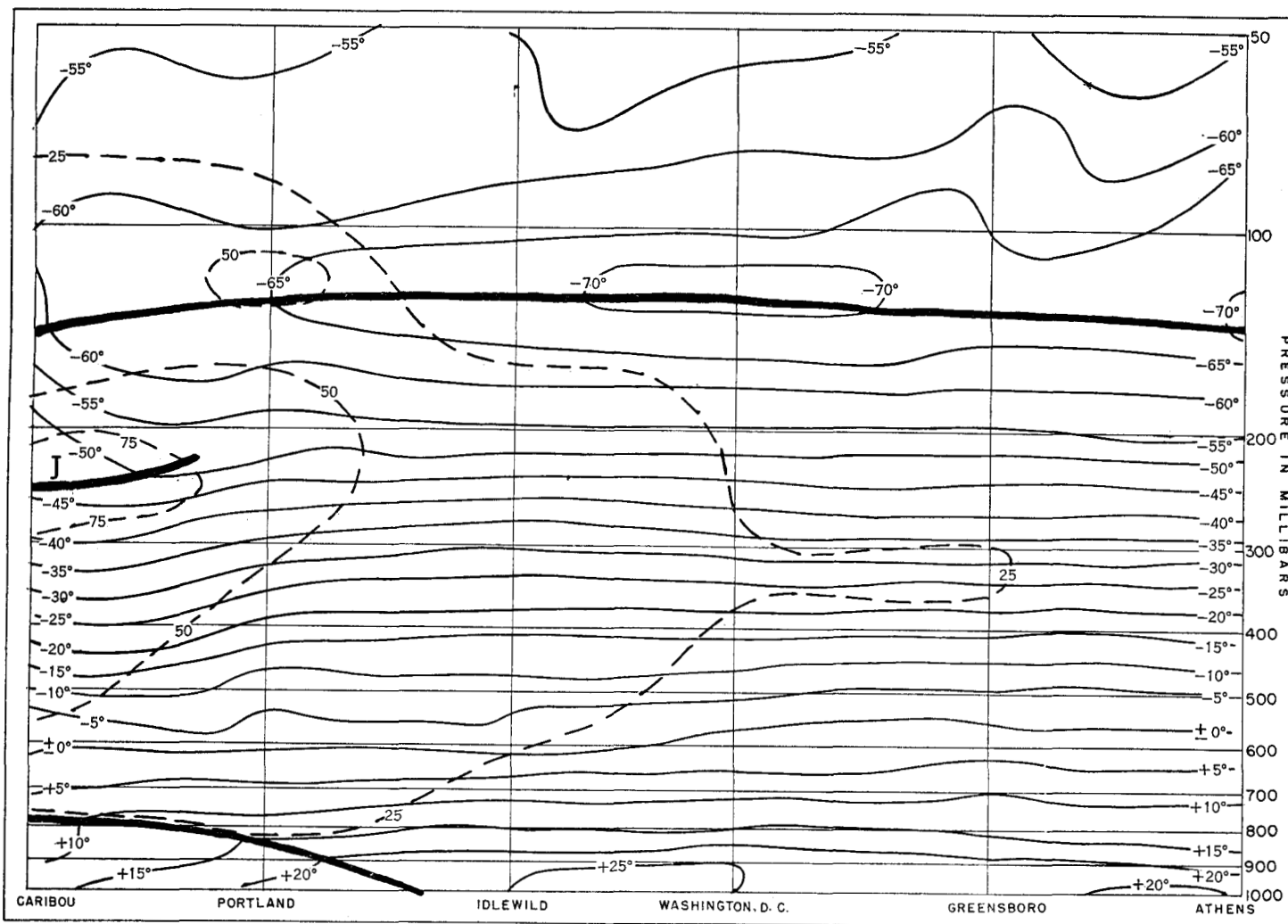


FIGURE 6.—Vertical cross section, Caribou to Athens, at 1200 GMT, July 21, 1957. Thin solid lines are isotherms in degrees C. Dashed lines are isotachs in knots. Heavy solid lines are fronts and tropopause leaves.

prevailed on the east coast) and 1200 GMT, July 24 (when the trough pattern prevailed on the east coast). A cross section which included both New York and Washington, D. C., was considered desirable since both places had experienced high maximum temperatures on the 21st and appreciably lower ones by the 24th. The technical desirability of a section normal to the mid and upper troposphere flow for both synoptic times was also a consideration. Fortunately, all of these desirable qualities could be met with cross sections from Athens, Ga., to Caribou, Maine.

As shown in figure 6, the only notable baroclinic features in the troposphere were in the frontal zone (lower left hand corner of the diagram) and between Portland and Caribou above the 500-mb. level. Two tropopause leaves are shown in the cross section. Along the upper one, the potential temperature varied from  $359^{\circ}$  at Athens to about  $376^{\circ}$  at Caribou. The lower leaf with a potential temperature of about  $339^{\circ}$  at Caribou could not be readily detected in the soundings for Portland or the other stations to the south. The tropopause leaf at Caribou

did not quite satisfy the arbitrary definition for a "first tropopause" which has been defined as "the lowest level at which the lapse rate decreases to  $2^{\circ}$  C./km. or less, and averages  $2^{\circ}$  C./km. or less for at least 2 km. above. In addition . . . the lowest tropopause must satisfy both of the following conditions: (a) It must occur between the 600 and 30-mb. levels, and (b) its temperature must be colder than  $-30^{\circ}$  C." [8]. The requirements for a "first tropopause" at Caribou were satisfied at about the 150-mb. level. Sufficient stabilization, however, occurred at 250 mb. to indicate the existence of another leaf.

Seventy-two hours later (fig. 7) the troposphere had become considerably more baroclinic as the change from anticyclonic to cyclonic conditions took place and as the polar air displaced the tropical air; the frontal zone now stretched over the entire distance covered by the cross section. The stratospheric picture was more complicated with three tropopause leaves of varying intensities. The jet, which was now of double structure, was located between the two lower leaves; the lowest leaf was a continuation of the low leaf at Caribou in figure 6. Stratospheric

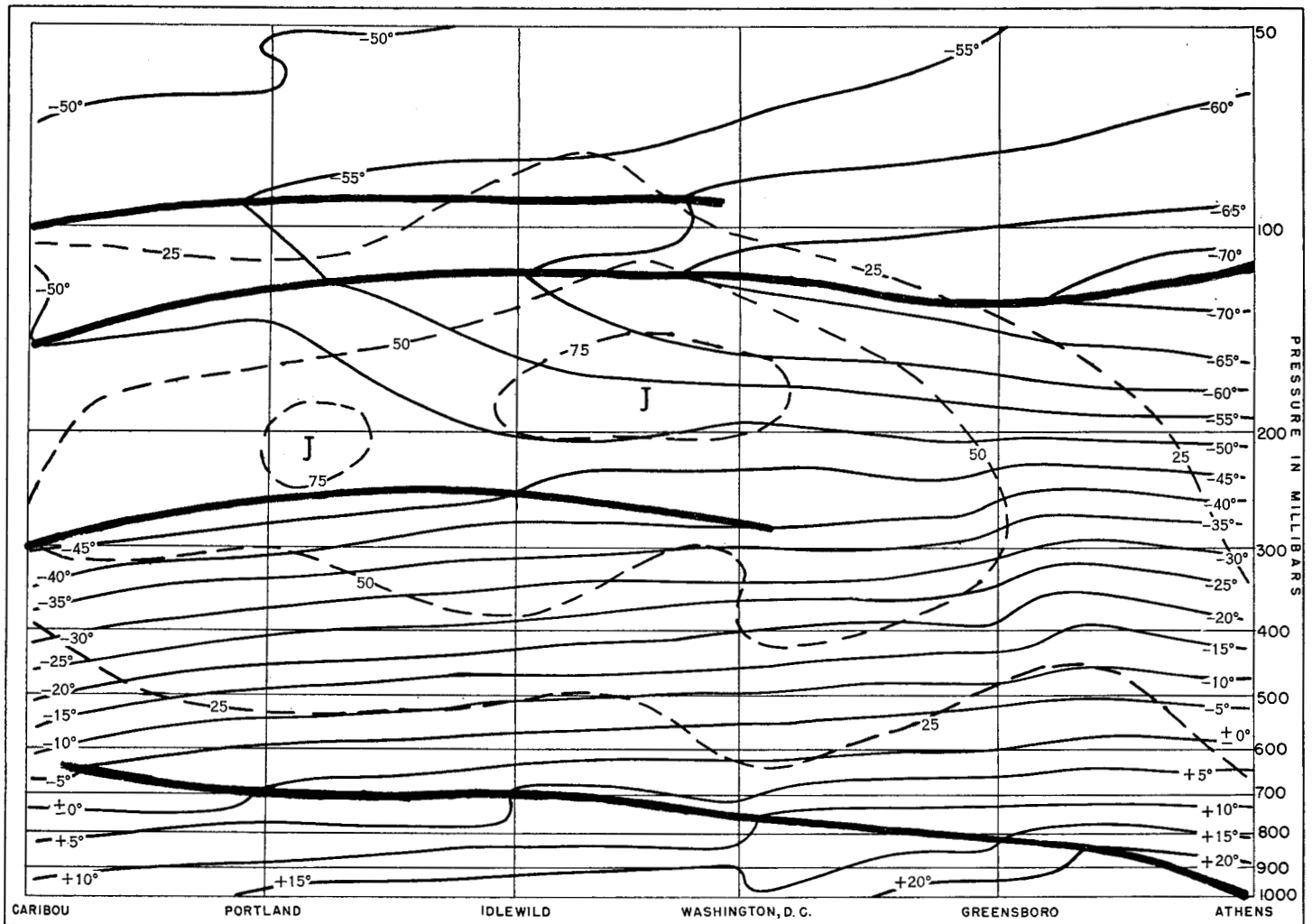


FIGURE 7.—Vertical cross section, Caribou to Athens, at 1200 GMT, July 24, 1957. Thin solid lines are isotherms in degrees C. Dashed lines are isotachs in knots. Heavy solid lines are fronts and tropopause leaves.

warming had occurred to the north of Greensboro. This is more readily indicated by the cross section in figure 6.

The 72-hour change in temperature and isohypses are shown in figure 8. The major axis of the positive isallotherm field was almost horizontal and was found at about 130 mb. The pattern of the isallohypses was more complex, with the most pronounced feature being the nearly horizontal axis near 250 mb. between Portland and Washington. This axis of greatest height change was noticeably out of phase with the axis of greatest temperature change. Between Portland and Caribou the major axis of the height falls was tilted more toward the vertical with a second center of height falls indicated in the vicinity of or somewhere northward of Caribou. The lack of sufficient high level data precluded further interpretation in that area.

#### 7. THE FORECAST PROBLEM

Abnormally high surface temperatures are most often found below upper air (500-mb.) ridge patterns. To terminate the existence of these large positive temperature anomalies it would, therefore, be necessary to replace

this upper air pattern with a more cyclonic one. In essence then, to forecast from the 1200 GMT, July 21 map (fig. 1) the termination of the incipient heat wave over the middle Atlantic seaboard, it would be necessary to foresee the development of a good trough aloft over this same area. This major trough would have to be a development, essentially, of the short-wave trough located over Hudson Bay.

Inspection of the situation leads one to conclude that reasoning from jet stream principles would not be fruitful in this case. In the classical case of "digging", the winds to the rear of a deepening trough are significantly stronger than either the winds at the base of the trough or immediately in advance. Such was not the case. The wind field immediately to the rear of the Hudson Bay trough could be seen from the 500-mb. isohypses to be relatively weak. The two main jet streams in the general area were not too favorably located. One jet was located somewhat too far to the north. Its west-east orientation, in addition, was not the most desirable one for anticipating "digging". The other jet appeared to be located too far to the south

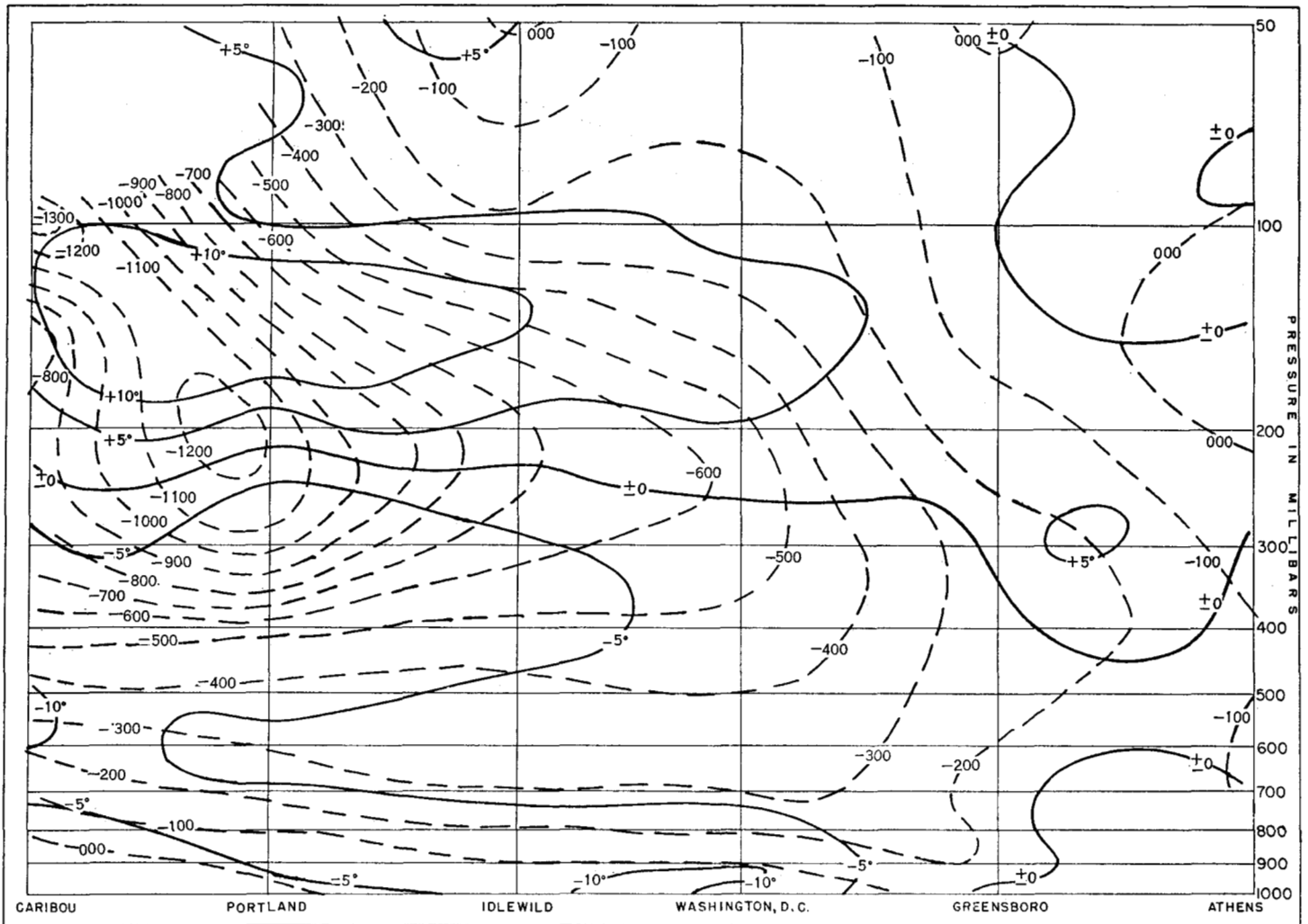


FIGURE 8.—Vertical cross section, Caribou to Athens, with 72-hour changes from 1200 GMT, July 21, 1957, to 1200 GMT, July 24, 1957. Isalohypses (dashed lines) are labeled in hundreds of geopotential feet per 72 hours. Isallotherms (solid lines) are labeled in degrees C. per 72 hours.

to be of much influence. Inferring a development primarily or solely from jet reasoning would thus appear to be unwarranted in this case.

A principle often used for predicting intensification states that deepening of a trough will continue as long as the winds in the cold air moving into the trough continue from north to northwest [9]. In this case there was no cold air advection of any consequence from the direction north to northwest for this rule to be of any avail.

Application of the upstream influence effect was not deemed apropos. This would attribute downstream deepening of the Hudson Bay trough as a consequence of upstream ridge building. Unfortunately there was no discernible building of the upstream ridge as of 1200 GMT, July 21, although 12 hours later building of the upstream ridge was definitely taking place.

One apparently fruitful attack on the problem involved a tie-in with events occurring in the Gulf of Alaska. In that region significant falls had been occurring by 1200

GMT, July 21 both at the surface and aloft. The mean flow chart for that time (fig. 4) also indicated advection of cyclonic vorticity into that same area. This combination of events, experience has shown, would tend to favor the movement inland of any trough immediately off the west coast of the United States with the resultant establishment of the intensifying trough in the Gulf of Alaska as the new off shore major trough. In essence, the new long-wave trough position off the west coast would be located farther west than previously. The establishment of this new long-wave trough position off the west coast, unless accompanied by a "sympathetic" retrogression of the long-wave trough position off the east coast, would result in a wavelength of much too large a value to be in accord with either the theoretical requirement of the Rossby long wave formula or the empirical knowledge of the experienced forecaster. It would therefore be logical to conclude that retrogression of some consequence would have to take place in the East. This would of necessity require a westward shift of the ridge from the Atlantic

seaboard and the replacement of the pattern in this area by one of more decidedly cyclonic character.

In actuality the pressure pattern outlook summary (FSUS) issued by NAWAC for 1200 GMT, July 21 called for a broad scale pattern change of this general nature based upon reasoning of this sort. In addition, a 24-hour previous outlook warned of possible readjustment of the long-wave positions during the next few days as a consequence of developments appearing in the Gulf of Alaska.

In addition, there appears to be some reason to believe that development of the Hudson Bay short-wave trough was helped by a "phasing" with the weak trough which had appeared in central Nebraska by 1200 GMT, July 21. Some contribution to this development must also have come from "phasing" with the cyclonic vorticity remnant of the southern portion of an older east coast polar trough. After shearing off, this older trough was steered clockwise around the east coast upper-air High to a favorable position for merging with the weak trough in Nebraska, and ultimately this joint product "phased" with the Hudson Bay trough.

It is interesting to note that the 72-hour 500-mb. prognostic chart issued by JNWP Unit (using their current quasi-barotropic model) and based upon the 500-mb. chart of 1200 GMT, July 21 as the initial map, showed definite east coast retrogression. In fact, the main defect in the portion of the numerical prognostic for eastern United States was that, ironically, too much retrogression was predicted.

#### ACKNOWLEDGMENTS

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